MIDAS: Modelling, Inversion and Data Assimilation to prepare SWOT mission

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1. Introduction and objectives

The SWOT observation of sea surface height (SSH) at scales below 100 km is expected to lead to a breakthrough in our understanding of fine scale dynamics in the open ocean, including kinetic energy cascades toward dissipative scales, the processes involved in vertical exchanges of heat and tracers between the surface and the ocean interior, and the ways how internal tides interact with the eddying ocean dynamics. Several SWOT mission goals will be fulfilled provided we are able to reconstruct high resolution gridded 2D maps of SSH and estimates of the 3D dynamics of the ocean upper layers. These reconstructions will in turn be possible or more accurate if we can predict and understand some of these dynamics beforehand. The MIDAS project will advance the knowledge of fine scale ocean dynamics and develop methods to make the best reconstructions from SWOT and ancillary data.

2. Proposed activities and approach

The MIDAS project is organized along four threads of scientific activities. It also includes a fourth thread dedicated to synergistic activities. The four threads are summarized below.

Improving our understanding of ocean dynamics and scales interactions below 100 km

Better understanding ocean dynamical processes below 100 km is a key step toward the interpretation and the processing of SWOT data for the reconstruction of ocean surface and interior circulations. MIDAS particularly focuses on (i) documenting the statistics and the predictability of fine scale motions, (ii) the interactions between wave and non-wave motions, (iii) the impact of air-sea couplings on cross-scale energy exchanges, and (iv) the preparation of the processing chains for the statistical analysis of SWOT ocean data.

Developing methods for the reconstruction of 2D products from SWOT and nadir altimeters

The reconstruction of gridded maps of ocean surface quantities from SWOT and nadir altimeters, illustrated on Fig. 1, is made difficult by SWOT sampling patterns. The low-frequency, 21-day repeat period combined with the high, 2-km resolution of the data challenges our ability for this reconstruction. MIDAS addresses this question from three perspectives: (i) the development of mapping algorithms, particularly to fill the large gaps between two satellite passes, (ii) the separation of wave and non-wave motions, with a specific interest into machine learning techniques, and (iii) the reconstruction of mesoscale surface currents using data from multiple sensors.

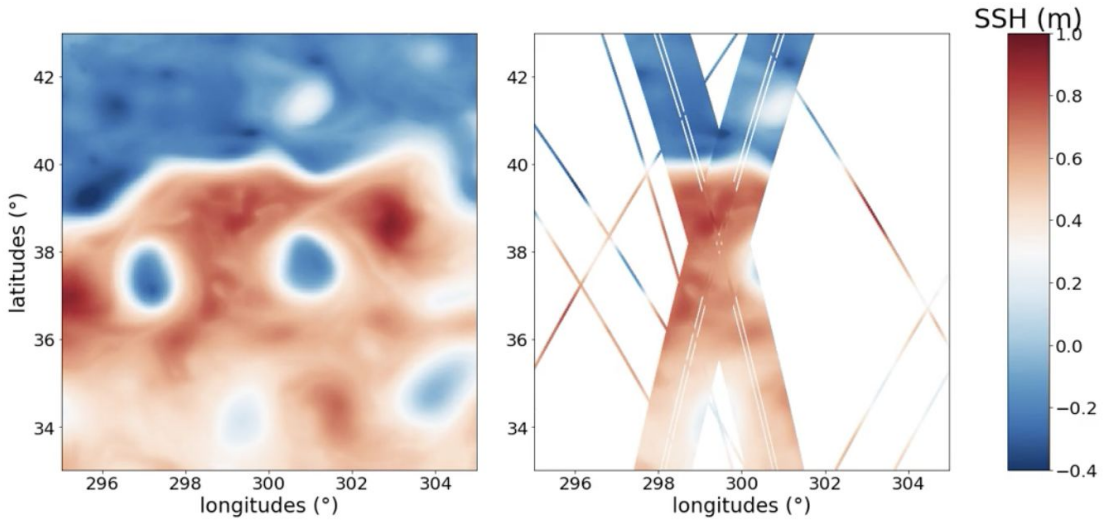

Figure 1: Illustration of SSH mapping from SWOT and nadir altimeters. The SSH field shown on the left must be reconstructed from a time sequence of data of the type shown on the right.

Preparing the reconstruction of the 3D upper ocean dynamics in the SWOT fast sampling phase

Estimating the three-dimensional structure of upper ocean dynamics is essential for quantifying the vertical exchanges occurring between the surface and the interior ocean, but is difficult due to the sparsity of observations of the vertical structure of the ocean. The specificities of SWOT Fast Sampling Phase, with its 1 day-repeat orbit and the data collected with in-situ campaigns, are expected to allow to reconstruct the three dimensional structure of upper ocean circulation. The MIDAS project includes (i) research on new methodologies to address this inversion problem, then two applications (ii) in the Western Mediterranean sea, with a focus on vertical velocities in support of the BIOSWOT-AdAC project proposed by F. d'Ovidio and collaborators, and (iii) in the Western Pacific Ocean, with a focus on internal tides in support of the SWOT-ST project proposed by L. Gourdeau and collaborators. Both applications are combined with cruises planned during the SWOT fast sampling phase.

Contribution to SWOT-ST collaboration and interaction with the wider community

MIDAS also includes (i) the evaluation and the distribution of data from the eNATL60 model simulations, performed at 1/60° resolution over the North Atlantic, with or without tidal forcing, and (ii) the organisation of ocean data challenges to accelerate the resolution of inverse problems posed by SWOT scientific objectives.

3. Data, tools and methodologies

The MIDAS project rests on tools, methods and collaborations developed during the past SWOT Science Team project.

NEMO-eNATL60 simulations

The two NEMO-eNATL60 simulations are fully described at https://github.com/ocean-next/eNATL60. They simulate the North Atlantic Ocean circulation at a 1/60° resolution, with or without tidal forcing. The simulation with tidal forcing is illustrated on Fig. 2.

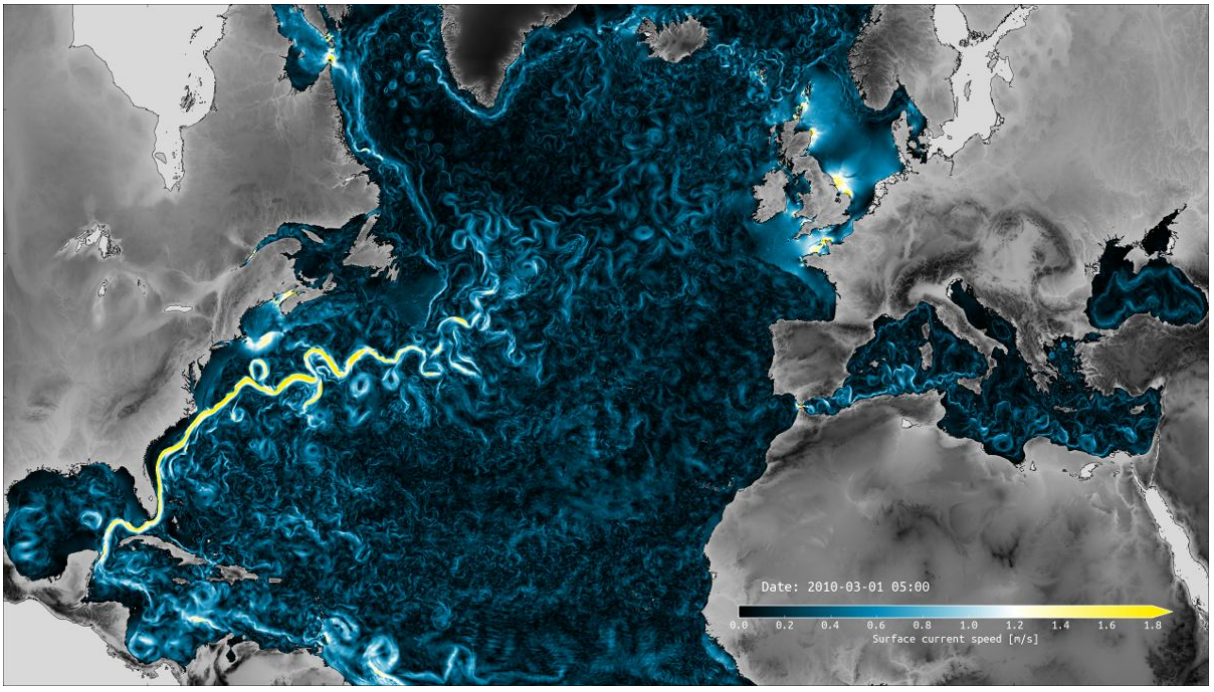

Figure 2. eNATL60 domain. The field shown is a snapshot of surface current speed.

Data analysis tools

Numerical tools are used for advanced analysis of ocean model simulations, either to better understand the dynamics or to evaluate the performance of reconstruction methods. The MIDAS team is extensively using (and contributing to) the software ecosystem around PANGEO community (https://pangeo.io). An example of such methods for spectral calculations (Ajayi et al, 2020) is shown at https://github.com/adeajayi-kunle/powerspec.

The ocean SWOT simulator

The ocean SWOT simulator is used to simulate SWOT observations, including realistic errors, and develop reconstruction methods. The simulator is accessible at https://github.com/SWOTsimulator

SWOT data processing and assimilation tools

The reconstruction of the ocean circulation will be essentially based upon already developed SWOT data processing methods (e.g. https://github.com/meom-group/SWOTmodule, Gómez Navarro et al, 2020) and data assimilation methods (Metref et al, 2019, 2020). Machine learning tools will also be used, as in Lguensat et al (2020).

4. Anticipated results for SWOT

Anticipated results from MIDAS project are as follows:

- a refined understanding of ocean dynamics at scales <100km (predictability, interaction with internal waves);
- the development of analysis pipelines for the statistical analyses of SWOT ocean data;
- the development of improved mapping algorithms for reconstructing gridded maps of sea surface height and currents from SWOT ocean data;
- estimations of three-dimensional ocean circulation at two SWOT-AdAC sites.

5. References

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